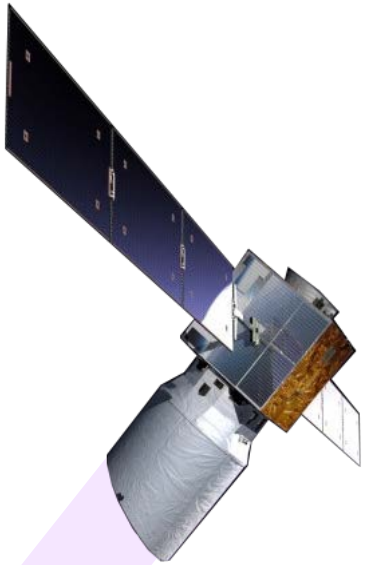
Airborne wind lidar measurements in the North Atlantic in 2009 supporting ESA's Aeolus mission

Uwe Marksteiner

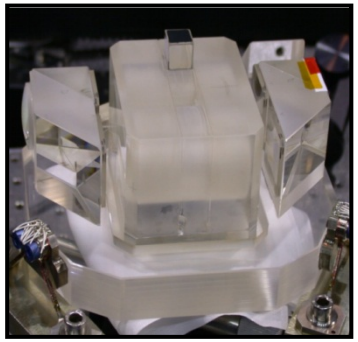
O. Reitebuch, S. Rahm, C. Lemmerz, B. Witschas



DLR

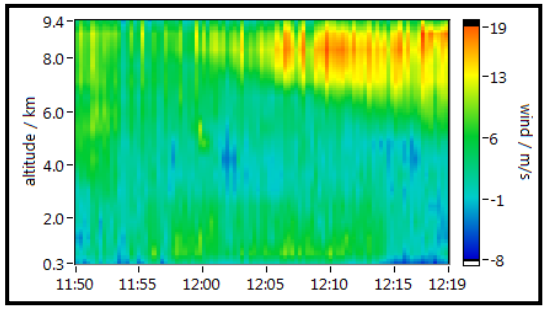
Outline

- ADM-Aeolus - the first wind lidar in space



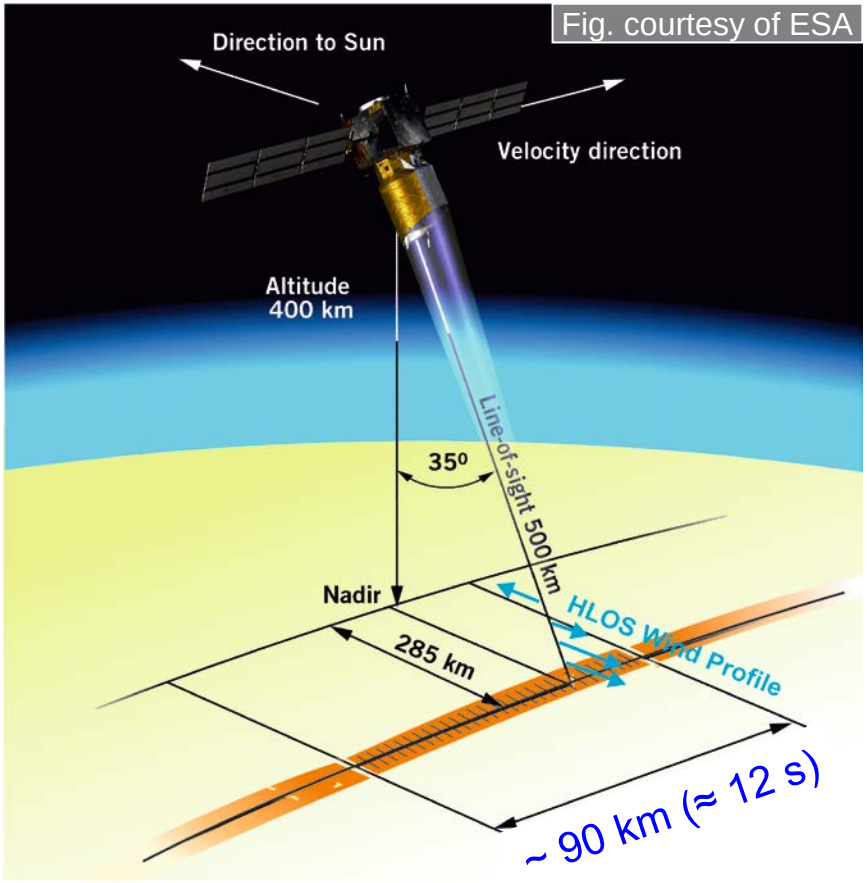
- Instrument description

- Airborne campaign for pre-launch validation



- Wind measurement & statistical comparison with a 2-µm reference Wind Lidar

► Atmospheric Dynamics Mission - ADM-Aeolus



- Launch planned for 2015
- 1st wind lidar and
  1st high spectral resolution lidar in space
- 355 nm (UV)
- Measurement of vertical profiles of wind speed (in 0 - 25 km altitude)
- Error requirements:

random:	< 1-3	m/s
systematic:	< 0.4	m/s
wind speed dependent:	< 0.7	%

➔ **Characterisation of instrument**
➔ **Validation of measurement principle**
➔ **In particular the calibration strategy**
➔ **Validation of measurement results**

► Optical remote sensing with lidar

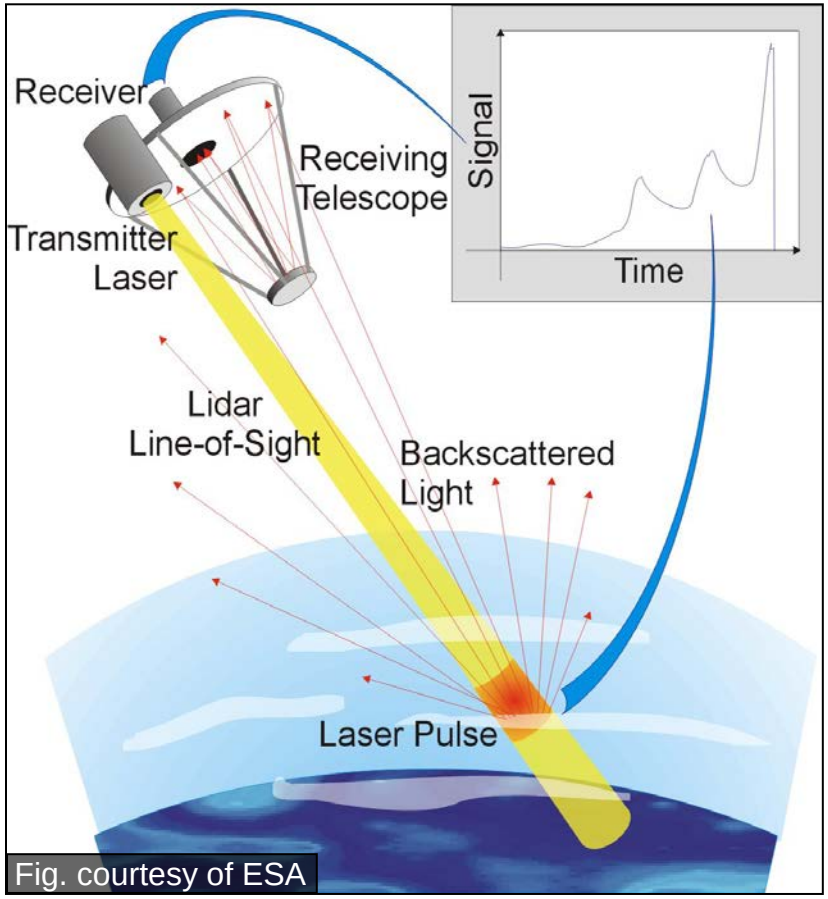


Fig. courtesy of ESA

LIDAR (Light detection and ranging)

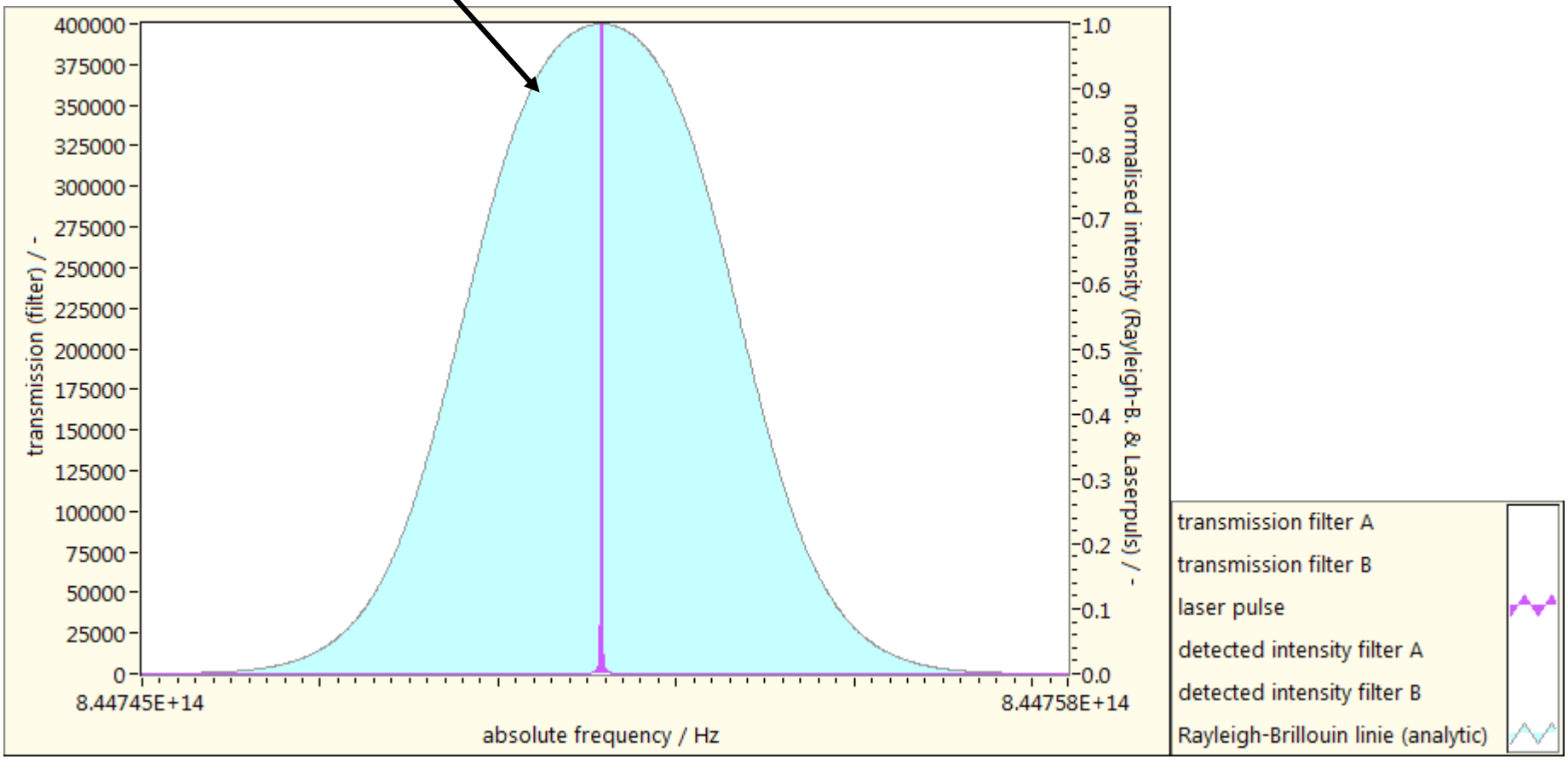
- Laser pulses transmitted into the atmosphere
- Light scattered on molecules and particles
- Scattered light collected by a telescope
- Range resolved analyses of signals
- Depending on the state of the scatterer

➔ Allows measuring e.g.:

- Distance
- Concentration of trace gas (CH_4, O_3, H_2O, …)
- Properties of particles
- Temperature
- Wind speed

► Double edge technique

Witschas 2011:
- analytical model of the Rayleigh-Brillouin line



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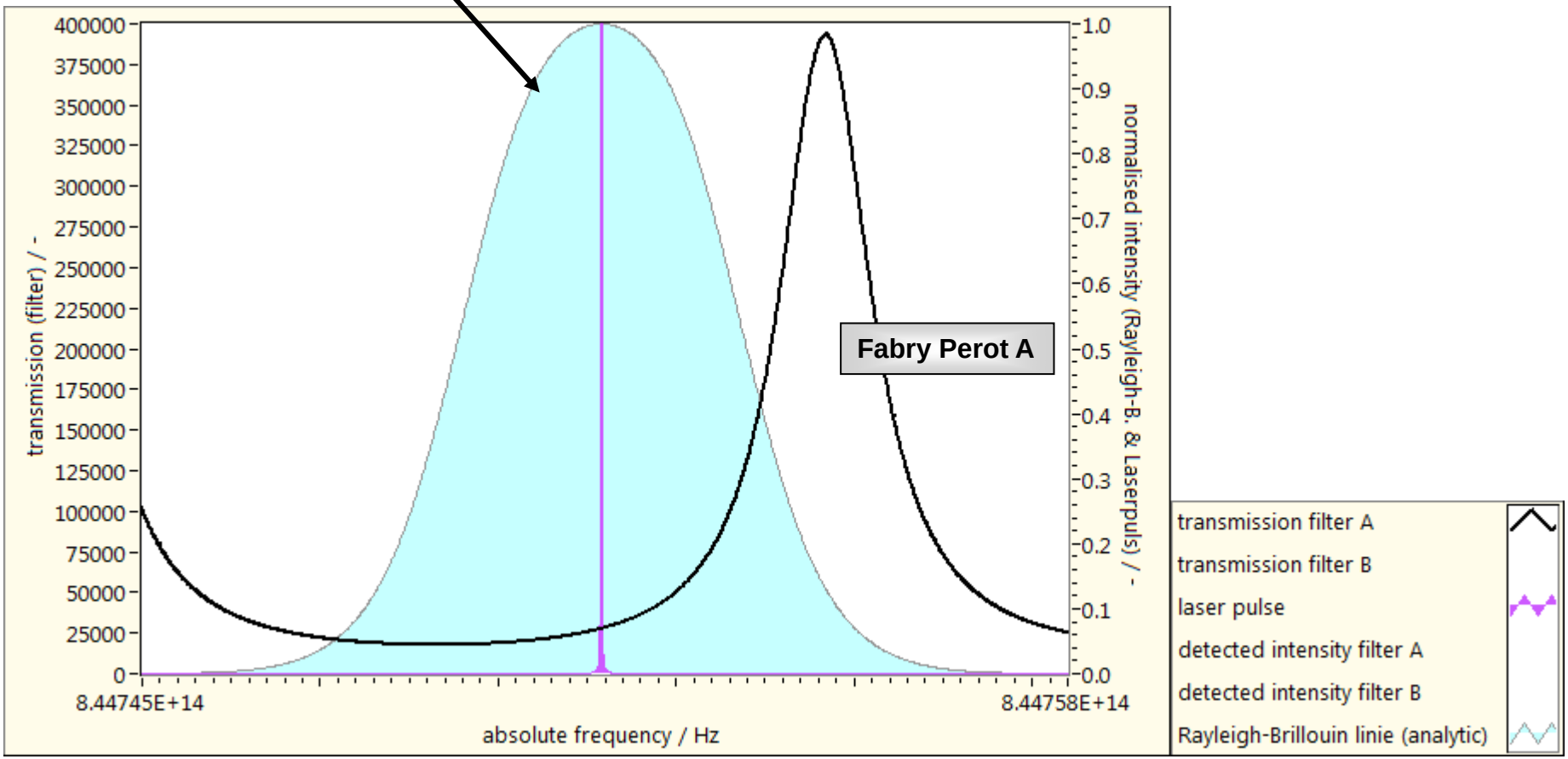

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Witschas 2011:
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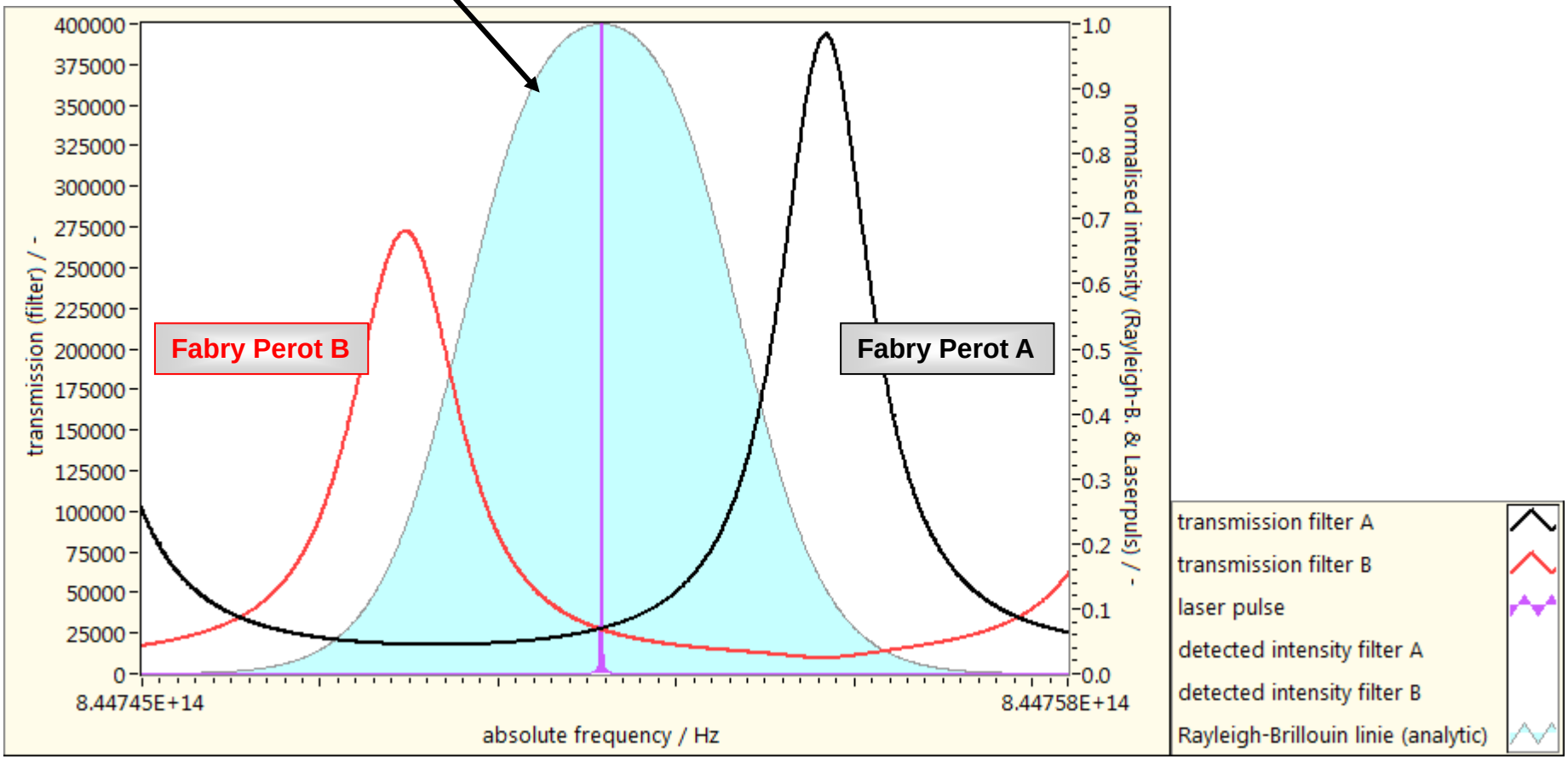
Chanin 1989, Korb 1998, Gentry 2000: ⇒ 2 filters!
→ Doubling of signal change
→ Increase of accuracy by a factor of 2
→ Desensitisation with respect to aerosol signal



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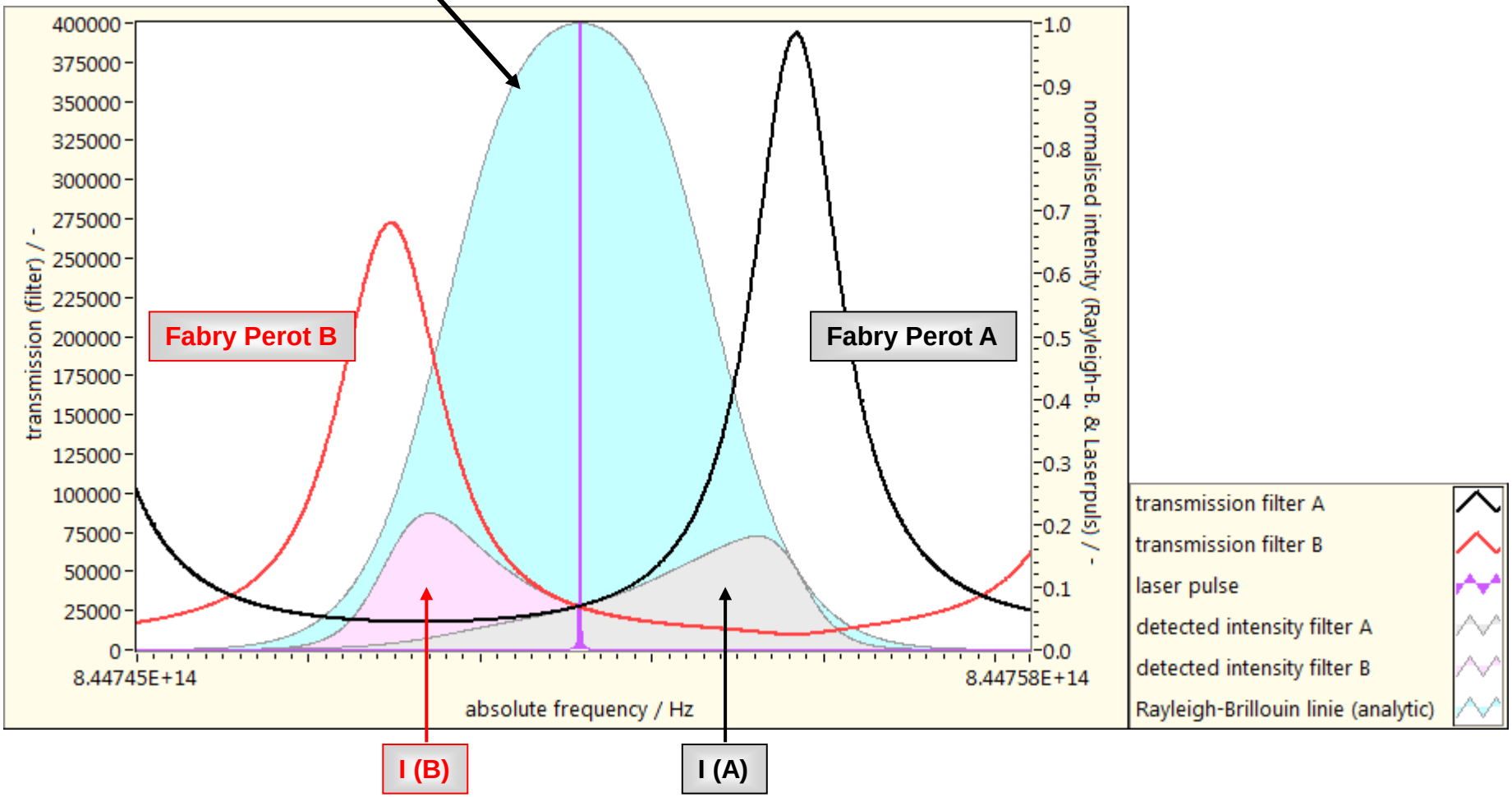

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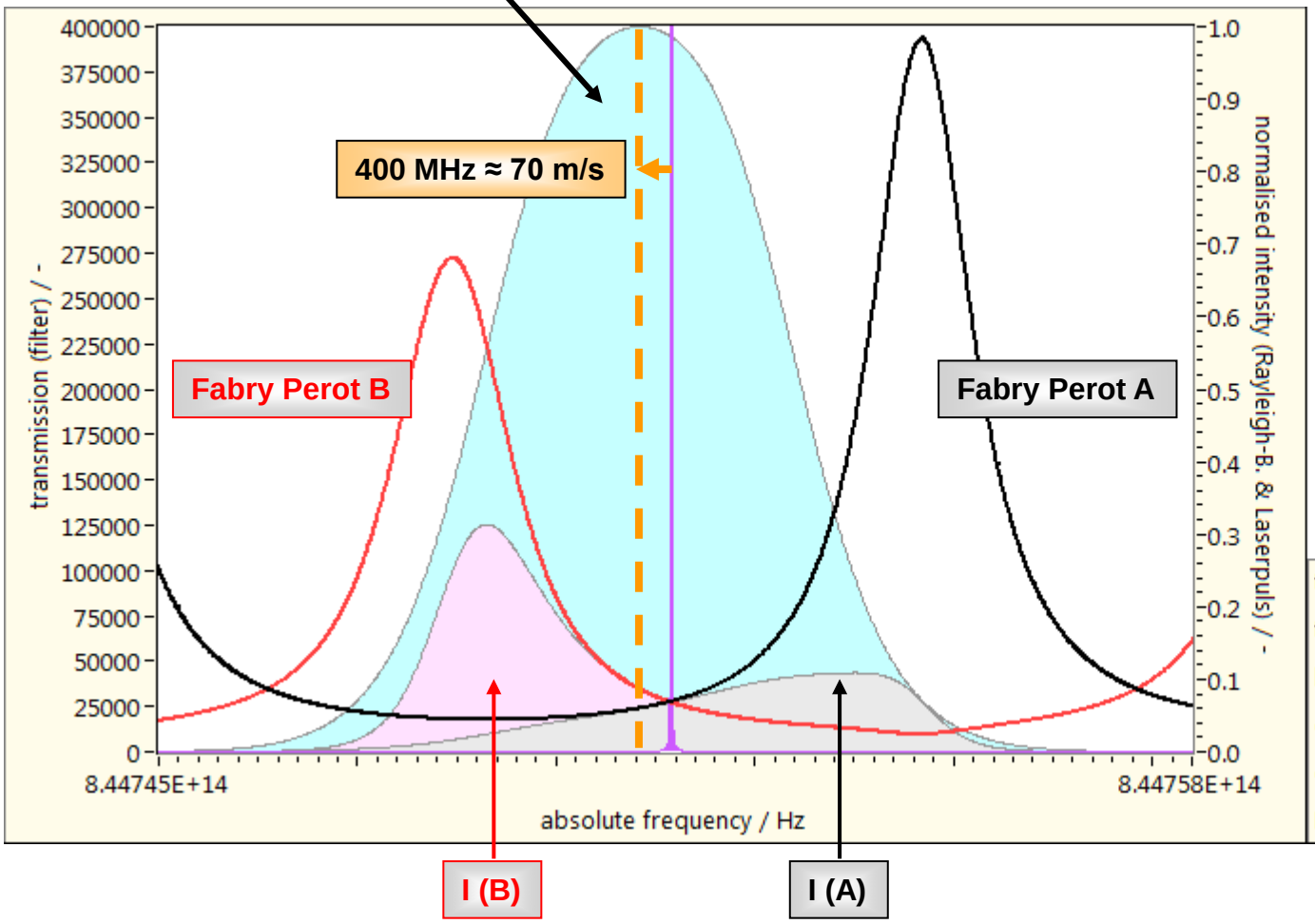


Doppler-equation:

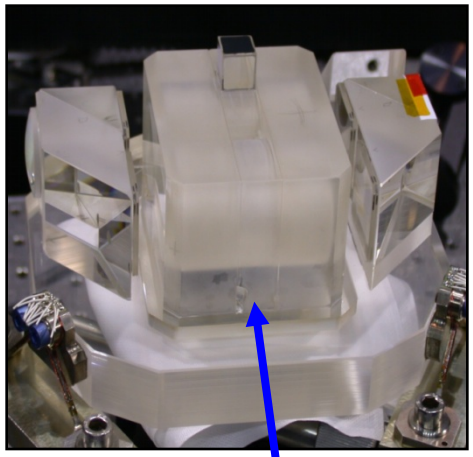
$$v_{LOS} = \frac{c}{2} \cdot \frac{\Delta f}{f_0}$$

$f_0 \approx 8.44 \cdot 10^{14}$ Hz
$\Delta f \approx 1 \cdot 10^{6}$ Hz

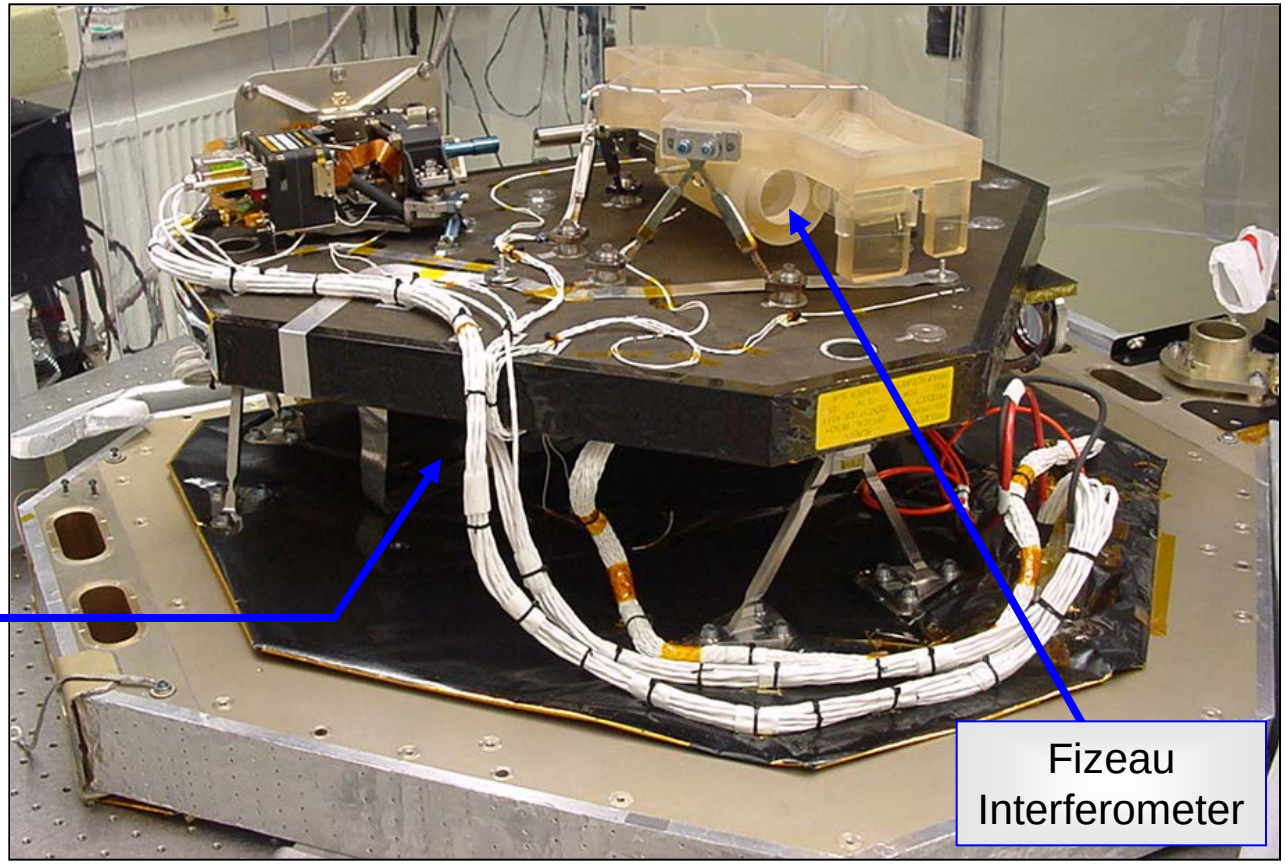
Jena → München
⇔
0.5 mm

►ALADIN Airborne Demonstrator (A2D) - receiver

- The optical receivers of the airborne demonstrator from DLR (A2D) and the satellite instrument (ALADIN) are almost identically constructed
- Complex design including about 60 optical elements



Fabry-Perot Interferometer



Fizeau Interferometer

Reitebuch et al. 2009

► A2D and 2-µm lidar in the Falcon aircraft

DLR Falcon Payload during flight campaign in Iceland 2009

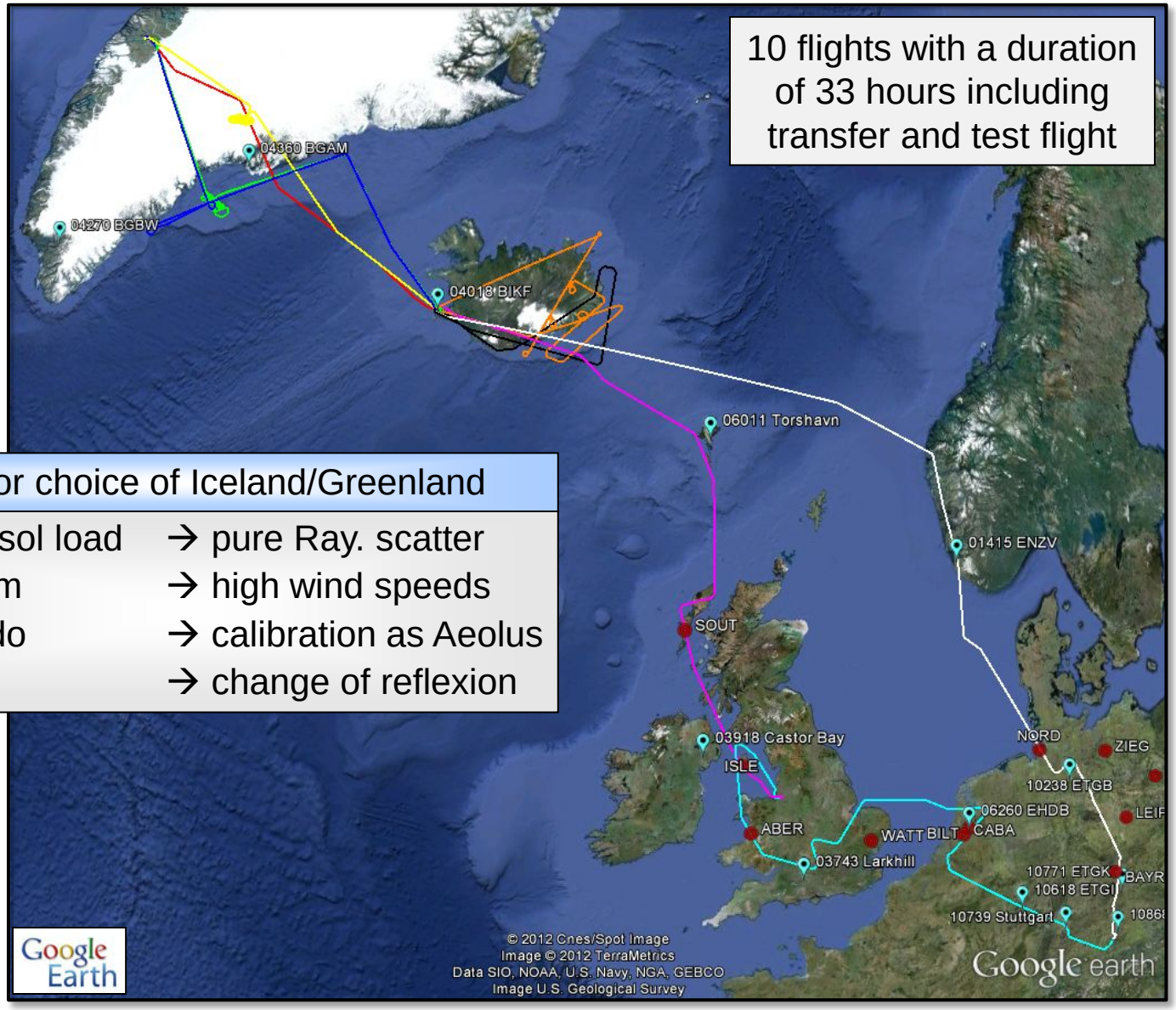
A2D receiver thermal hood

2-µm DWL electronics

A2D-telescope (Ø 0.2 m / 20°)

2-µm heterodyne Doppler Wind Lidar

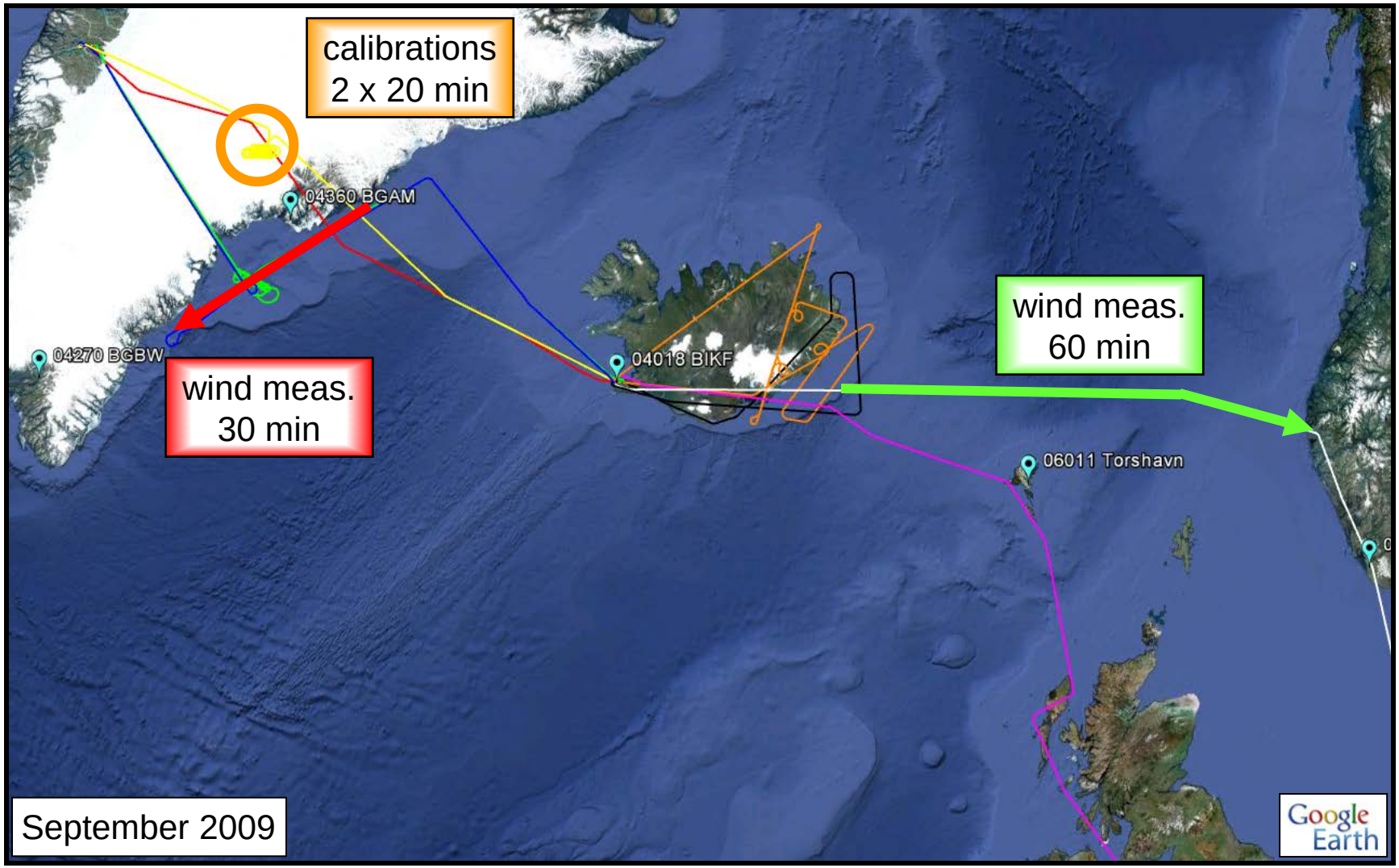
► Airborne campaign September 2009: all flight tracks



Reasons for choice of Iceland/Greenland

- low aerosol load → pure Ray. scatter
- jet-stream → high wind speeds
- ice albedo → calibration as Aeolus
- ocean → change of reflexion

► Flight tracks during calibration & selected wind measurements



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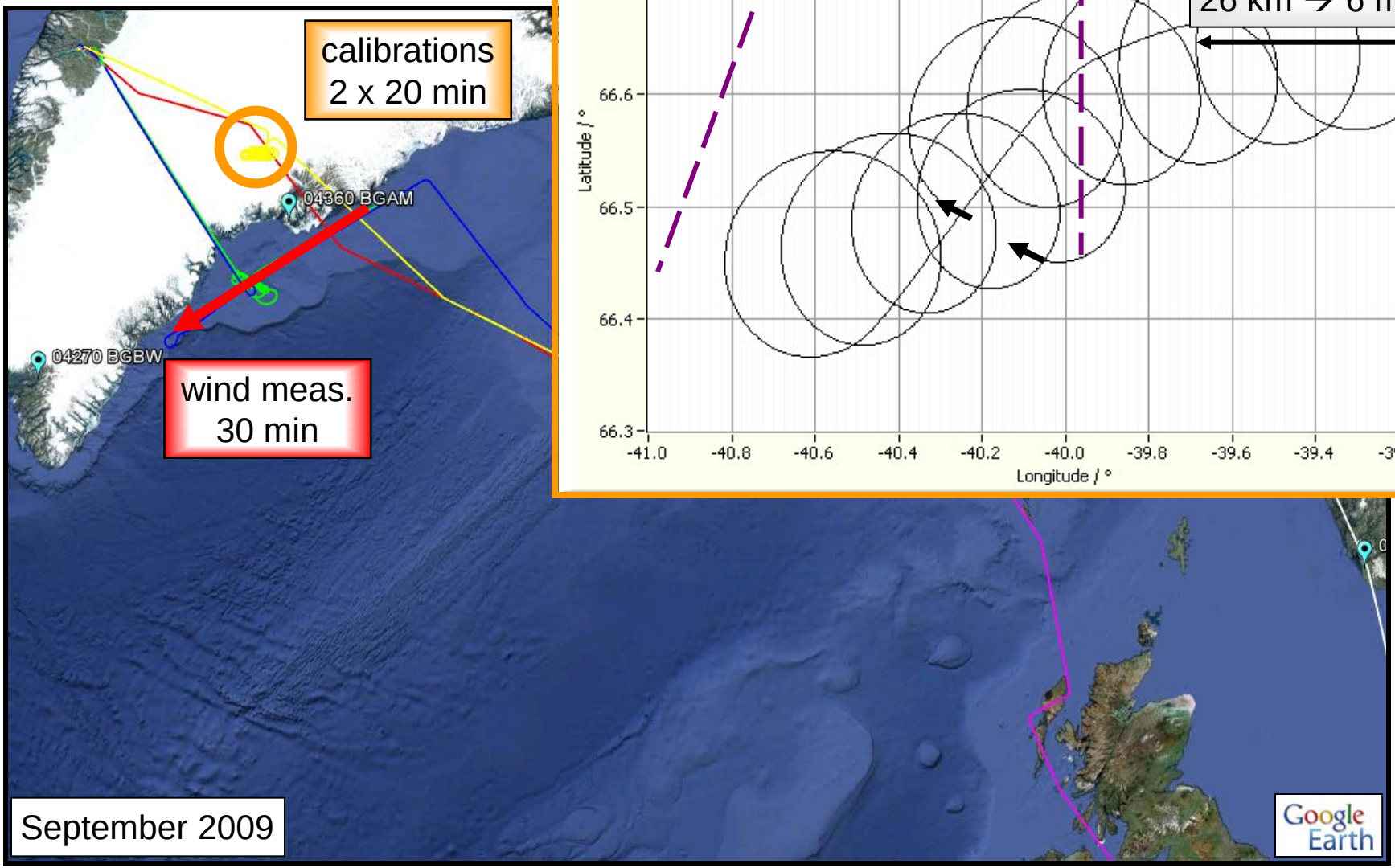
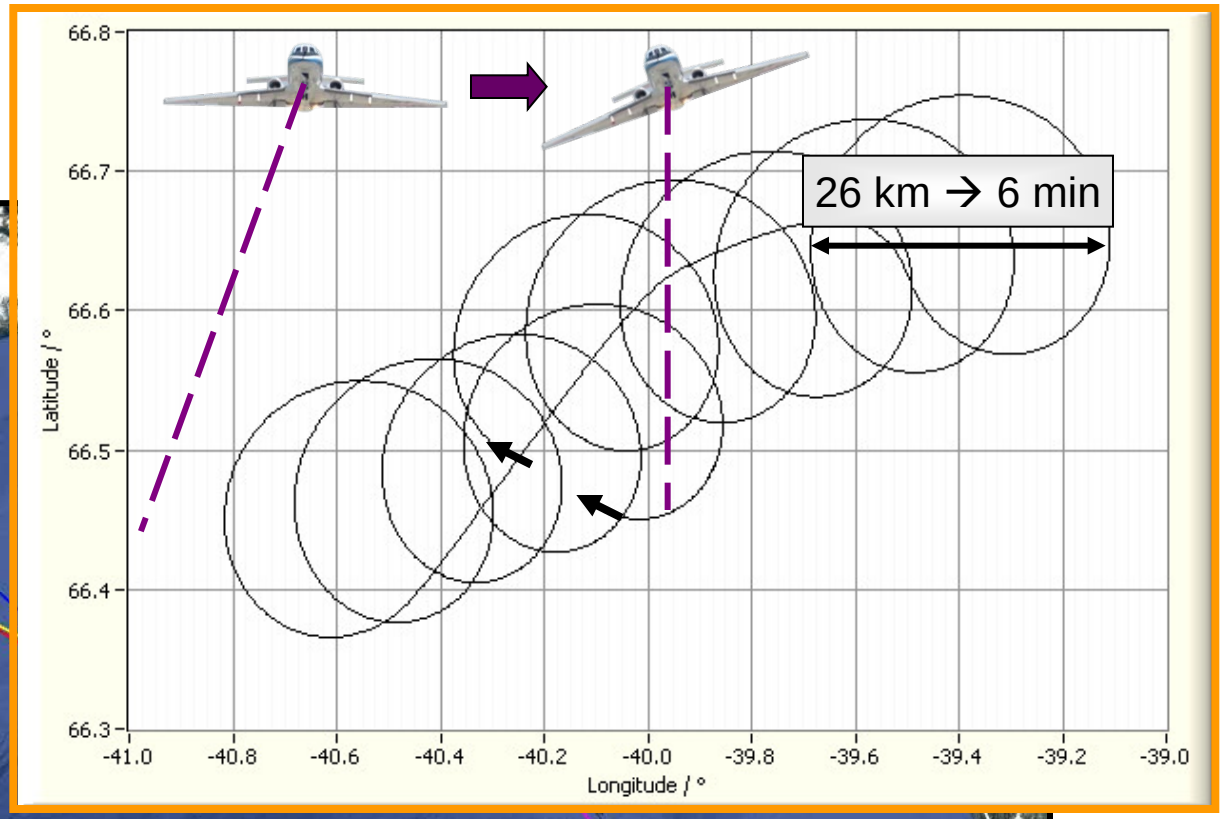


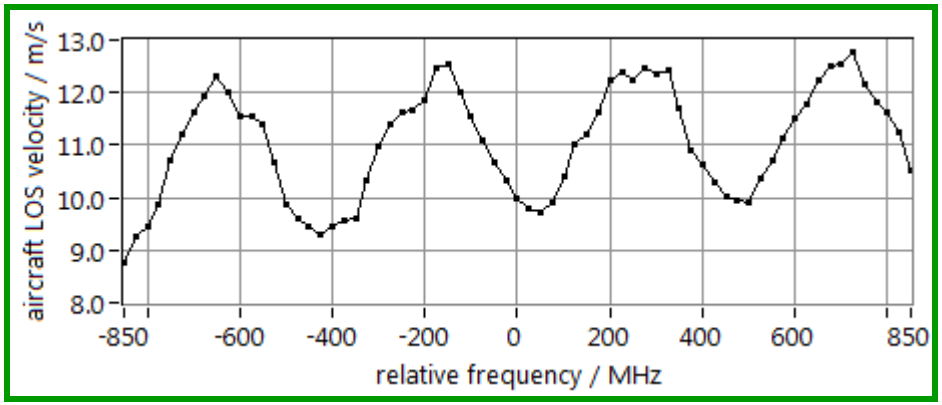


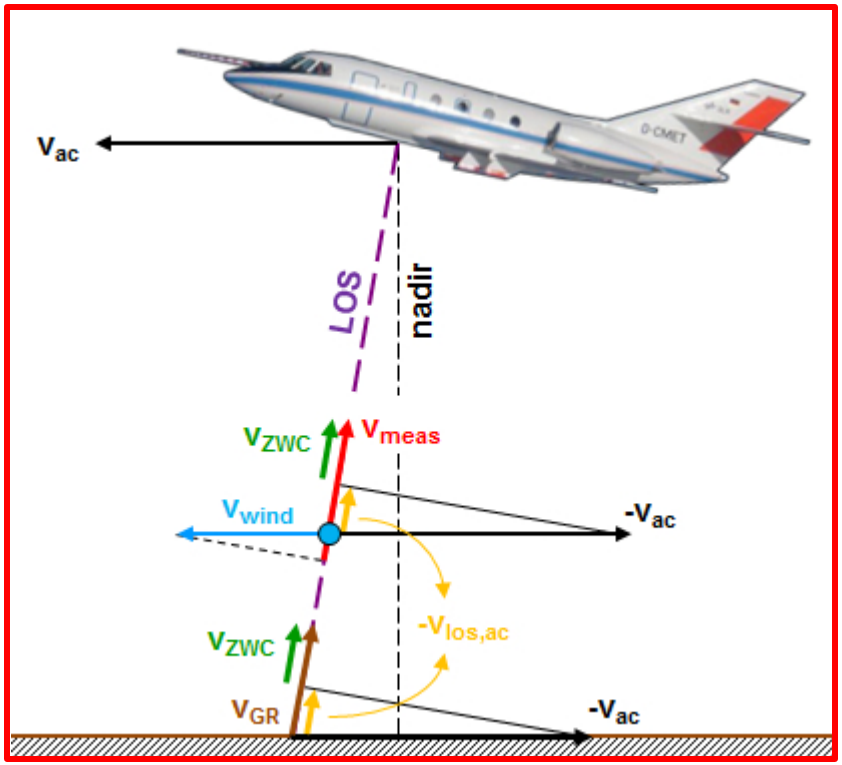
► Line-Of-Sight velocity and corrections

Additional virtual wind velocity induced by:

1. component of flight velocity into Line-Of-Sight direction (known)
2. instrument or flight velocity errors (unknown)

$$v_{LOS,wind} = (\Delta f_A - \Delta f_I) \cdot \frac{\lambda_0}{2} - v_{LOS,A/C} - v_{ZWC}$$

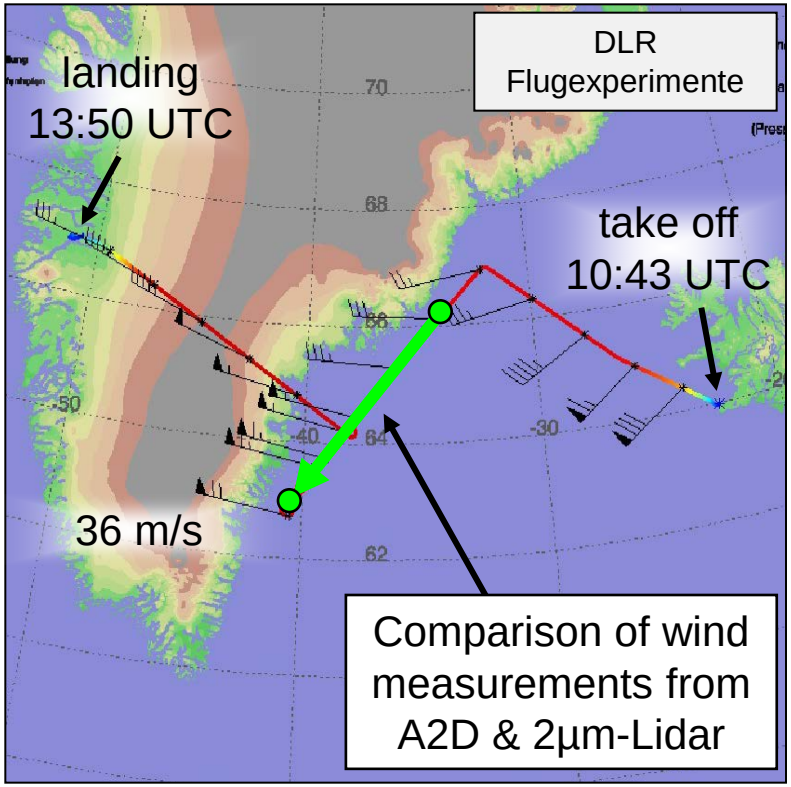


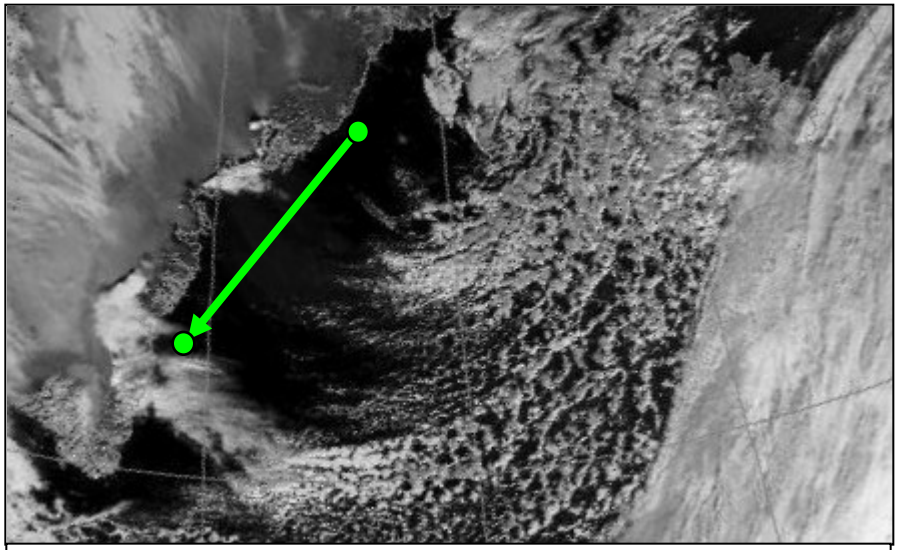


ground itself is not moving ➔ ground echo must lead to 0 m/s! ➔ Zero Wind Correction

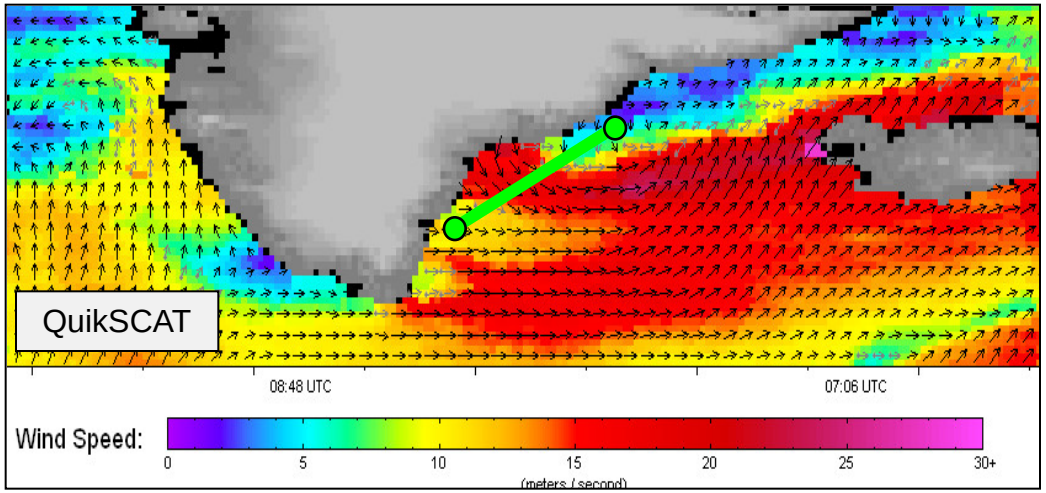
► Weather situation on 2009/09/26

Example: 26.09.2009 / 11:50 - 12:19 Uhr





NERC Satellite Receiving Station, Dundee University, Scotland, http://www.sat.dundee.ac.uk
TERRA (Kanal 6)



► Wind speed measurements on 2009/09/26

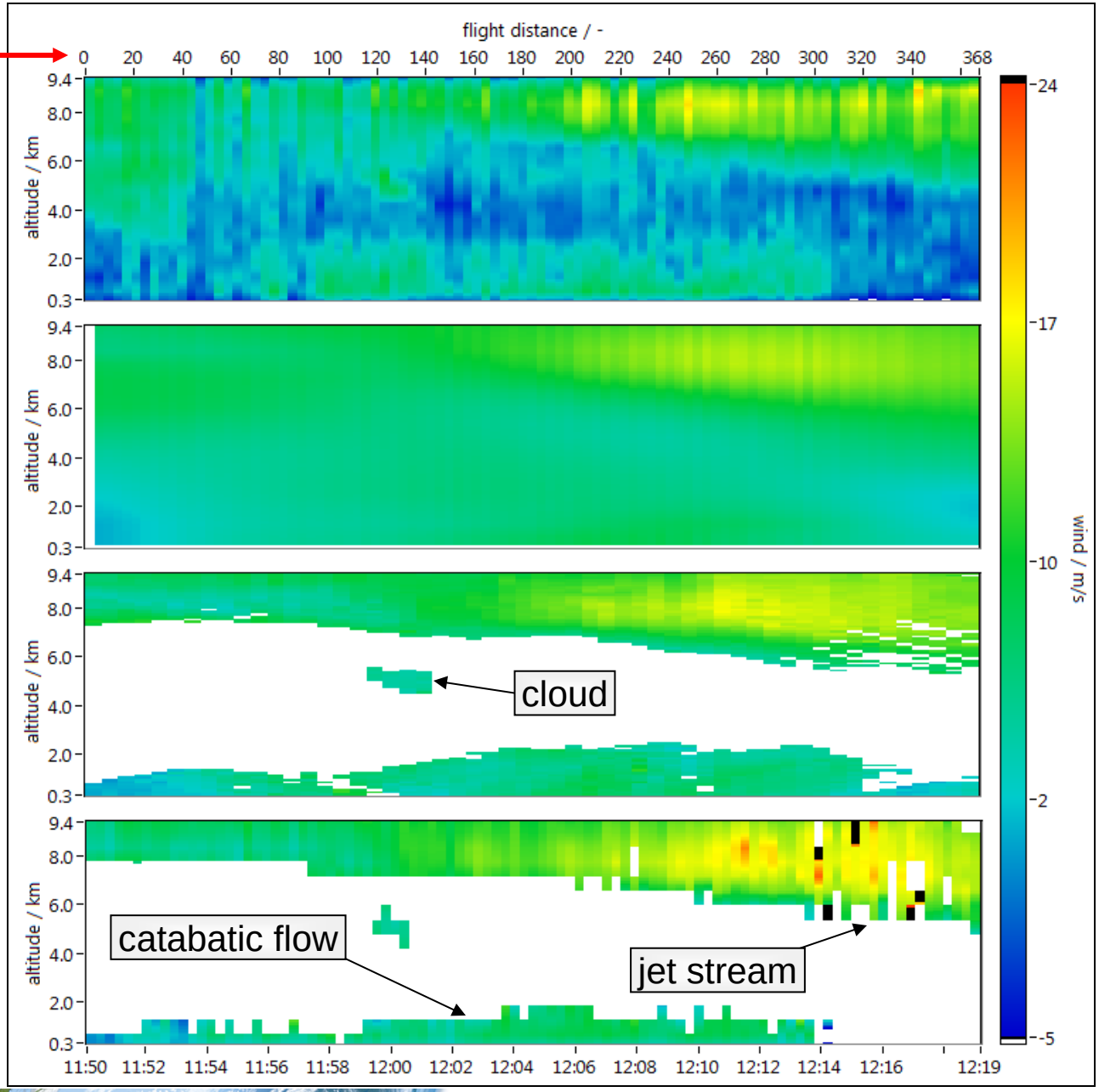
flight altitude: 10.4 km

A2D (Rayleigh)

ECMWF

2-µm lidar

A2D (Mie)



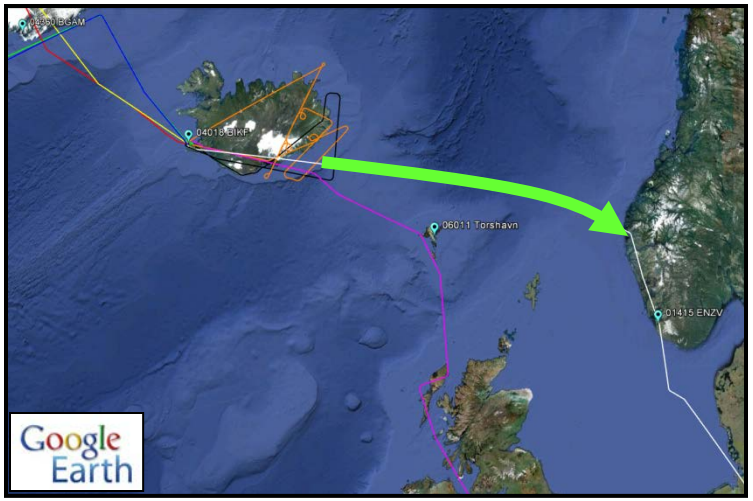
► Wind speed measurements on 2009/10/01

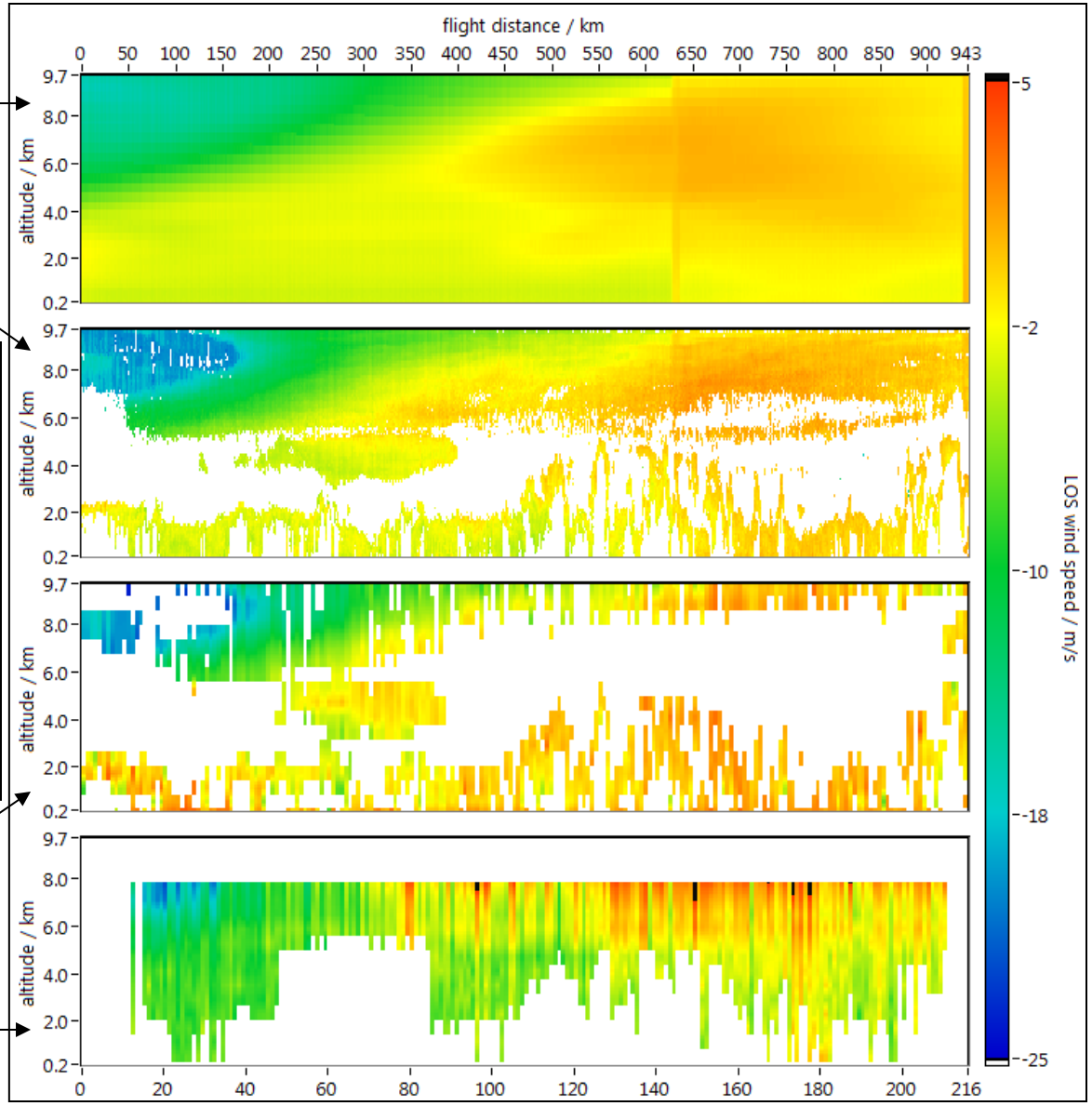
ECMWF

2-µm

Mie

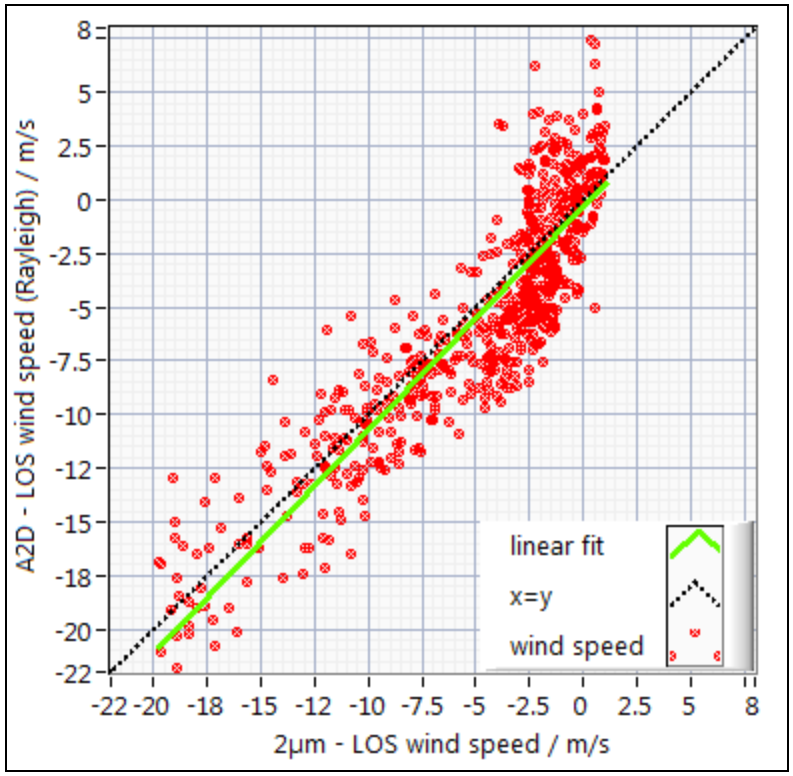
Rayleigh





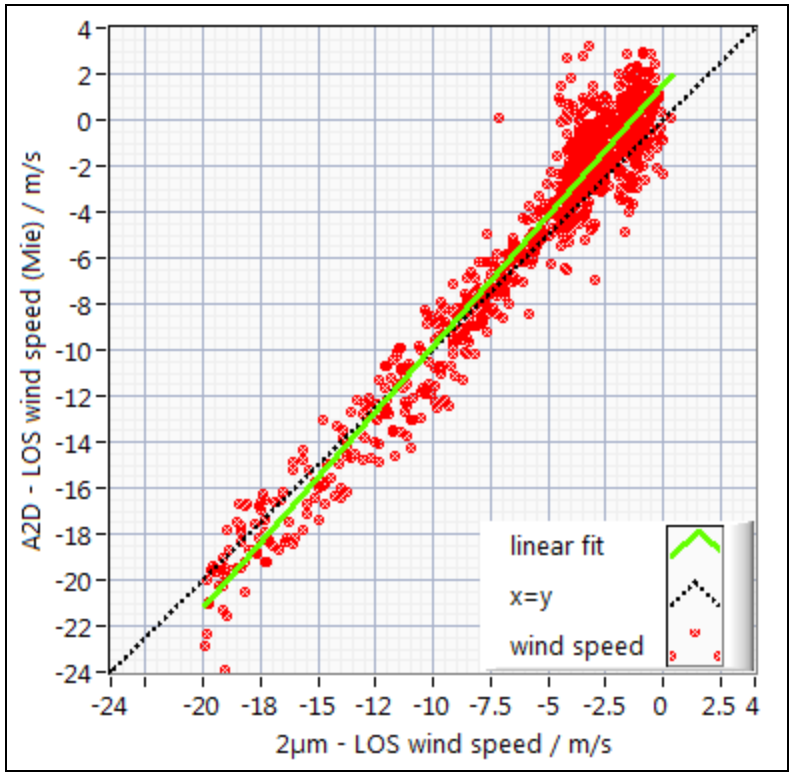
► Statistical comparison: A2D ⇔ 2-µm (2009/10/01)

Rayleigh



Slope:	1.04
Intercept:	-0.33 m/s
Correlation coeff.:	0.89
Std. Dev.:	2.53 m/s
Mean bias:	-0.52 m/s
# of points:	596

Mie



Slope:	1.14
Intercept:	1.51 m/s
Correlation coeff.:	0.97
Std. Dev.:	1.54 m/s
Mean bias:	0.75 m/s
# of points:	932

► Summary

- Measurements of wind profiles at all levels are of highest priority
- ESA's ADM-Aeolus satellite mission planned for launch in 2015
- DLR performed airborne campaign for pre-launch validation of ADM-Aeolus
- First successful flights worldwide with two wind lidar instruments on-board the same aircraft
- 10 flights (duration: 33 hours / incl. 2 calibrations) over North Atlantic region
- Comparison of A2D wind speed results against 2-µm lidar and ECMWF
- Good and very good agreement of Rayleigh respectively Mie wind speeds with 2-µm:

		Rayleigh		Mie
▪ Random error	/ m/s:	≈ 2.5 [Ray]	&	≈ 1.5 [Mie]
▪ Systematic error (intercept)	/ m/s:	≈ -0.5 [Ray]	&	≈ 1.0 [Mie]
▪ Wind speed dependent error	/ %:	≈ 5 [Ray]	&	≈ 12 [Mie]

The End